In July 1981, Sir Robin Day interviewed Brian J. Ford about his discovery of the oldest specimens in the history of the microscope. Details appeared next day in NEW SCIENTIST and NATURE and were widely reported in Britain and abroad. Later that year Ford marked the 150th anniversary of the naming of the cell nucleus by recreating the original experiments at an Extraordinary General Meeting organised by the Linnean Society at Burlington House, London. He showed to a crowded lecture theatre of distinguished scientists how a range of instruments thought to be 'dissecting microscopes' were capable of high magnifications, matching modern microscopes. Standard textbooks state that no early specimens have survived, that they would have been of poor quality, and that the images produced by early simple microscopes were distorted and indistinct. In each case Ford has disproved their traditional view. His research has involved many institutes throughout Europe, and the cooperation of leading scientists in Britain, Europe and the USA. The specialist findings which have won several awards have been published in the major science journals and many textbooks are currently being revised to incorporate these important discoveries, the story of which is told here for the first time.

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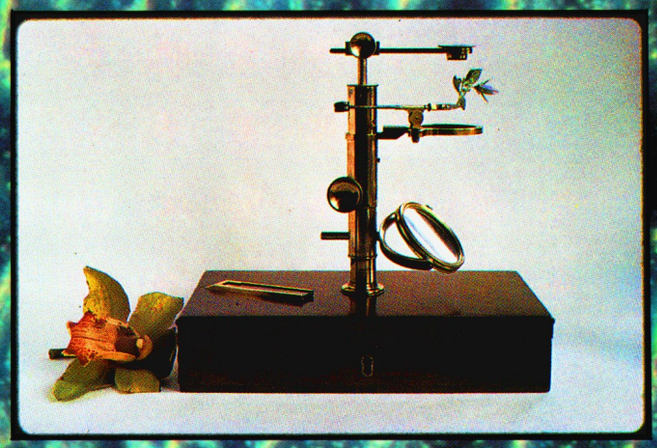
· SINGLE LENS · THE STORY OF THE SIMPLE MICROSCOPE · BRIAN J. FORD

· SINGLE LENS ·

THE STORY OF THE SIMPLE MICROSCOPE



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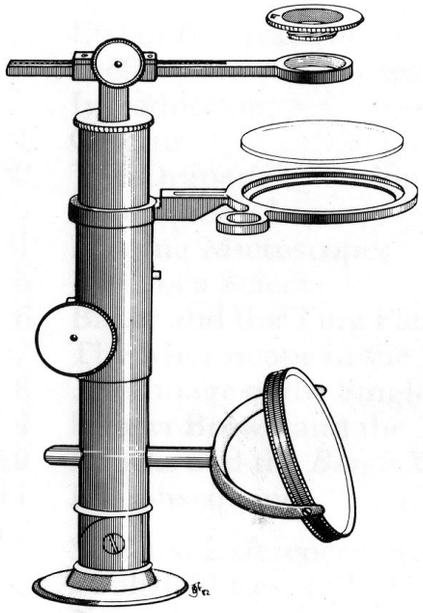

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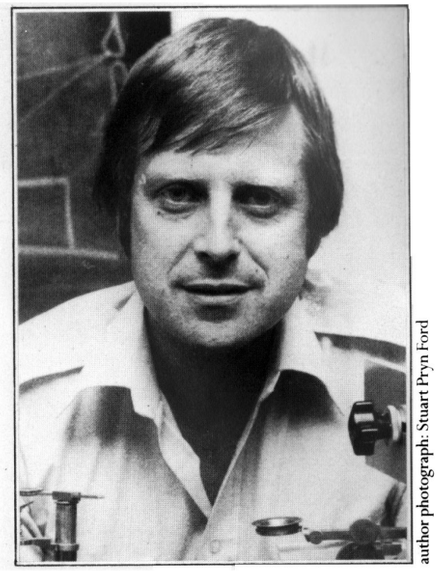

author photograph: Stuart Pryn Ford

Brian J. Ford is an authority on the microscope, a biologist, and is also well-known as an author, lecturer and broadcaster on science. He read biology as an undergraduate at the University College Cardiff, where he is now visiting research scientist in the Department of Zoology and a Member of the Court of Governors. He is a Member of the Institute of Biology, a Fellow of the Linnean Society, the Royal Microscopical Society, and of many other specialist organisations. His papers have been published in many scientific journals world-wide (including NEW SCIENTIST, NATURE and the BRITISH MEDICAL JOURNAL). He has also contributed to THE TIMES, ILLUSTRATED LONDON NEWS, and GUARDIAN, and broadcast on radio and television for nearly 25 years. His textbooks include MICROBIOLOGY AND FOOD, THE REVEALING LENS, and OPTICAL MICROSCOPE MANUAL, and among his general books are MICROBE POWER, THE EARTH WATCHERS, and his influential CULT OF THE EXPERT.

designed by: Robin Rout/Jeremy Woodhouse

The textbooks of science are being rewritten following the extraordinary disclosures described in this book. It has long been taught that no specimens survive from the early days of the microscope, but Brian J. Ford found nine specimen packets prepared three centuries ago by the 'father of the microscope' Antony van Leeuwenhoek, at a time when the foundations of modern biology were being laid. His research has revealed how the specimens were prepared and how the first sections were cut. He has identified the species Leeuwenhoek examined and even found some of the great man's cells adherent to the sections. He then recreated the pioneering experiments which gave us such fundamental concepts as the 'cell nucleus' and showed that many neglected early microscopes – formerly described as 'low-power dissecting instruments' – were actually capable of generating images of the highest quality. His story outlines a prolific and intense programme of research carried out in several countries. It is a vivid first-hand account of scientific investigation which brings alive the origins of the modern era of biology

Cover: The microscope at the Linnean Society with which Brown named the nucleus in 1831 during studies of orchids. Cells in the background are of *Allium* shown in dark-ground illumination using medium-power lens of Brown's microscope with rounded nuclei clearly visible.

Photographs by the Author

7 | The Microscope in the Field

Students of microscopical history know aquatic microscopes by a fuller title – 'the Ellis Aquatic Microscope'. As you might by now expect, the instrument was not invented by John Ellis at all. Apparently he encouraged Cuff to modify slightly his earlier design of an aquatic instrument, so that the bracket holding the lens could be turned round horizontally through 360° and also slid in and out, nearer to the main body of the microscope, or further away from it; so that the whole area of the stage could easily be examined. Some writers have insisted that this was the design's cardinal fault, since the slightest movement of the microscope would make the polyps contract. This is unlikely, firstly because the first aquatic microscopes (designed for the study of these organisms) did not have this feature, and secondly because the amount of movement imparted to the instrument by moving the lens arm sideways would be quite enough for them to detect – and not that much less than the amount of movement caused by gently moving the glass trough containing them from side to side. Furthermore, *Hydra* is not as sensitive as all that. Preparations of the living organisms can be gently moved around without causing them all to contract into little spheres. Since *Hydra* can accept small

movements of its surroundings without responding overmuch, and moreover since small movements of the lens arm are transmitted to the organism in either event, I question that widely quoted conclusion. In my view, the aquatic microscope was a simple design by Cuff, based on Baker's recommendations drawn from practical difficulties encountered during the use of conventional single-lens microscopes. It seems likely that the swivelling lens bracket resulted from manufacturing convenience.

Cuff emphasised that this new design of microscope made it possible to examine all kinds of specimens – sections, minerals, entire insects, blood and seminal smears, *and* larger living pond organisms like *Hydra* – by issuing in 1758 a pamphlet entitled 'The Description of a Double and Single Microscope Very Convenient to View All Sorts of Objects', which showed an aquatic microscope on to which a compound body could also be fitted, if desired. Six years later, John Dollond, the prominent microscope-maker, issued a pamphlet describing 'The Aquatic Microscope as Improved by John Ellis F.R.S.', and this showed a microscope with a main supporting pillar bearing a circular stage and a pivoted mirror beneath it, with a lens arm at the top of the instrument into which the lens-holders could be screwed. The needs for portability and stability were ingeniously met by having the microscope pack down into a box, on to the lid of which the pillar was mounted during periods of use.

The great Swedish naturalist Carl Linnaeus (1707–1778) used a simple microscope in his work of classifying the living organisms of the known world. The family name Linnaeus was taken by his father when he entered the University of Uppsala but he adopted the name of Carl von Linné on being ennobled in 1761. Linnaeus laid down the principles of modern classification, using the binomial system of two names, the genus and the species, which are familiar as the so-called 'Latin names' of biology. Not only did he systematise classification, but he gave us the unambiguousness on which taxonomists (i.e. classifiers) depend. A robin or a blackbird cover several different species, depending upon where you live, whilst a plover, a lapwing and a peewit are all different names for the same species. Of the names Linnaeus proposed in the eighteenth century, roughly 4,400 species of animals and over 7,700

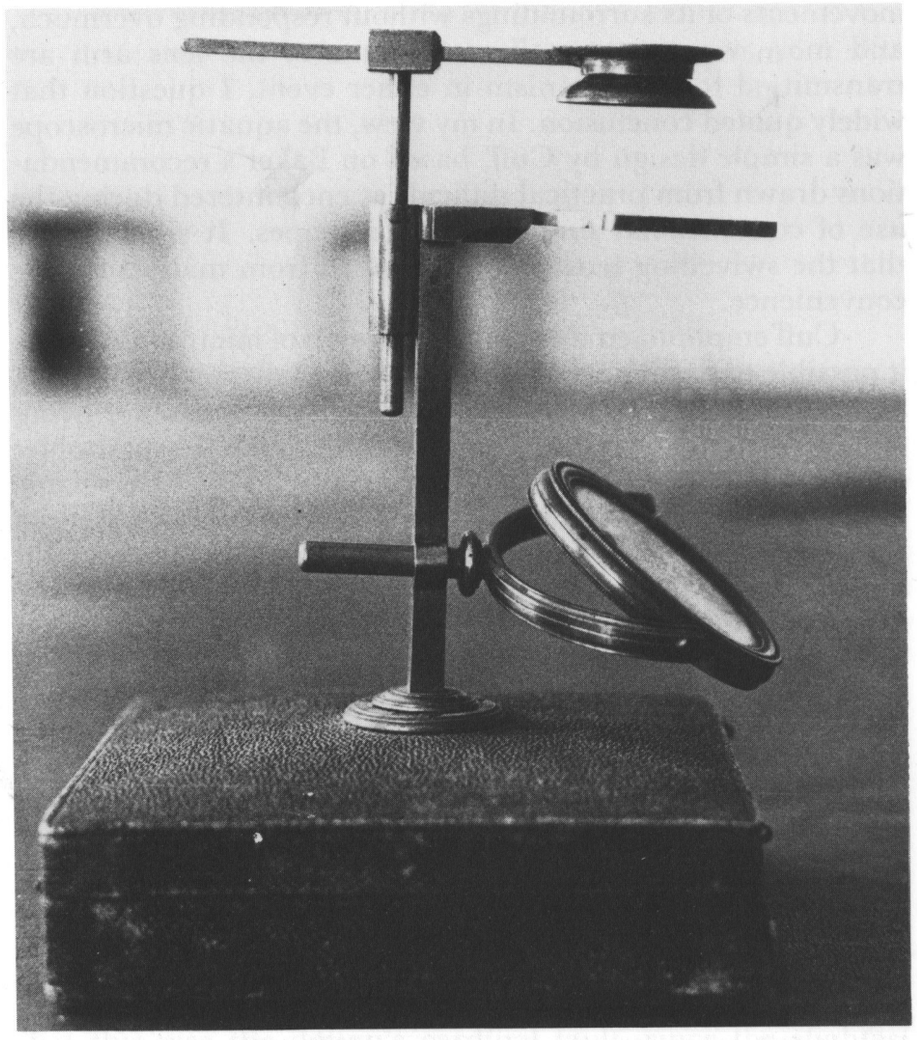

FIG. 19 An aquatic microscope marked by Cuff of London was used by Carl Linnaeus of Uppsala. It unscrews when not in use to stow into a fish-skin covered wooden case. Focusing is carried out by sliding the lens holder up or down in its friction mount.

species of plants still remain current; in each case the name bears the suffix 'L.', citing Linnaeus as the authority for the name. Our own species for example is *Homo sapiens* (L.). His *Species Plantarum* of 1753 together with his *Genera Plantarum* (5th edn, 1754) has been accepted by botanists as the starting-point for botanical nomenclature in general, just as his *Systema Naturae* Vol. I (10th edn, 1758) is the international reference for zoologists.

Linnaeus regarded the simple microscope as a normal and everyday part of his essential equipment. His ingenious approach to the classification of plants, for example, centred on the study of the sexual reproductive organs of each species – for flowering plants, this meant the structure of the stamen and pistil, the exact order of the flowering structures, rather than such irrelevant criteria as leaf shape, height or habitat. Many of these structures are hard to discern with the naked eye, and a portable microscope would have been necessary for much of his work.

In fact Linnaeus's microscope is preserved in the house attached to the old botanic garden at Uppsala, which he occupied during his professorship, and is now a Linnaeus museum. It is kept in a closed cupboard alongside his own writing desk and near the fur-covered bed in which he died. The microscope fits into a neat case covered with polished fish-skin in the manner of many eighteenth-century microscopes. It is made of brass and has a mirror, a circular stage, and a lens bracket typical of the aquatic microscope genre. The main supporting pillar is engraved with the words 'CUFF, London'. Two lens-holders are present, but one of them now lacks the glass lens. The remaining lens has a low magnification of only ×20, but as the diameter of a lens is decreased so its magnification increases, hence the smaller diameter of the missing lens shows that it would have been considerably more powerful.

The fact that Linnaeus used a microscope at all was overlooked for many years, indeed the *Journal of the Royal Microscopical Society* for 1905 (p. 253) published a letter from Sir Frank Crisp, a noted microscope collector, saying that he 'never heard that Linnaeus did' though he had since read a short sentence by Linnaeus in Latin indicating his use of a Cuff microscope for the examination of fungus spores. No doubt he used the high-power lens – now missing – for that work. However, this microscope cannot have been made until around 1750.

As noted above, in 1732 Linnaeus set out on his celebrated journey from Uppsala to Lapland, collecting, observing and classifying everything he saw. His journal, which is preserved in manuscript at the Linnean Society in London, records that he set out on 12 May 1732, old style, at eleven o'clock, 'being at

that time within half a day of twenty-five years of age'. His reference to carrying a microscope occurs in his introductory remarks and, since his account paints such a vivid picture of his preparations for the journey, it is interesting to have it in full:

> Having been appointed by the Royal Society of Sciences to travel through Lapland, to investigate the three kingdoms of Nature in that country, I prepared my clothing and other necessities as follows. My clothes consisted of a light coat of West Gothland cloth without folds, having small cuffs and a collar of shag; leather breeches; a round wig; a green leather cap, and a pair of top boots. I carried a small leather bag, half an ell [i.e. 30 cm] long, but somewhat less in breadth, furnished on one side with hooks, so that it could be shut fast and hung up; this bag contained one shirt; two pairs of false sleeves; two nightcaps; an ink-horn, pencase, microscope and spying-glass; a gauze cap to protect me occasionally from the gnats; this journal, a parcel of paper stitched together for drying plants, both in folio; a comb, my [manuscript] Ornithology, Flora Uplandica and Characteres generici. I wore a short sword at my side, and carried a small fowling-piece between thigh and saddle, an eight-angled stick graduated for the purpose of measuring. My pocket-book contained a passport from the Governor of Upsala, and the Society's recommendation.

The drawings Linnaeus brought back did not feature any high-magnification studies. His manuscript journal, for instance, shows a kind of cranefly that he labels alongside '6, Culex ibidem . . .' – *gnat from the same place* – shown hardly magnified at all, but with the veining of the wings excellently portrayed. The same figure is published in the translation of his *Tour in Lapland* edited by James Edward Smith, then president of the Linnean Society of London, in 1811. Smith amends the caption in his edited version to give Linnaeus's chosen name of this species, and omits Linnaeus's 'No 6' from the manuscript: 'The annexed figure represents a large kind of gnat caught in the same place (*Tipula rivosa*).' This species is now known as *Pedicia rivosa* (L). I imagine that Linnaeus used a lens for this drawing, even though it is not much larger than life. However,

so far as microbes were concerned, Linnaeus had a blind spot. The few names he proposed for micro-organisms were sometimes sound, but his general understanding of their systematic relationships was poor and even behind the times. On the other hand, it is clear that – without his simple microscope – Linnaeus's work would have suffered. He used it to good effect in his studies of higher plants, and in some cases of animal species.

There is one curious instrument associated with Linnaeus. It has a Latin inscription saying it was given to Bernard de Jussieu in memory of the pleasant association he had enjoyed with Linnaeus in Paris during 1738. The instrument is a compound microscope with a body of paste-board, and it came to light in 1887 in the lumber room of the Harmony Society, a German community at Economy, Pennsylvania. Ten objective lenses were found with the microscope, which has no trace of a maker's name and is of strange appearance. Why it was presented and how Linnaeus came by it are unknown. It may be that he gave it away, as an instrument he did not need – since his later Cuff microscope was a single-lensed instrument – or he may have purchased it especially for Jussieu

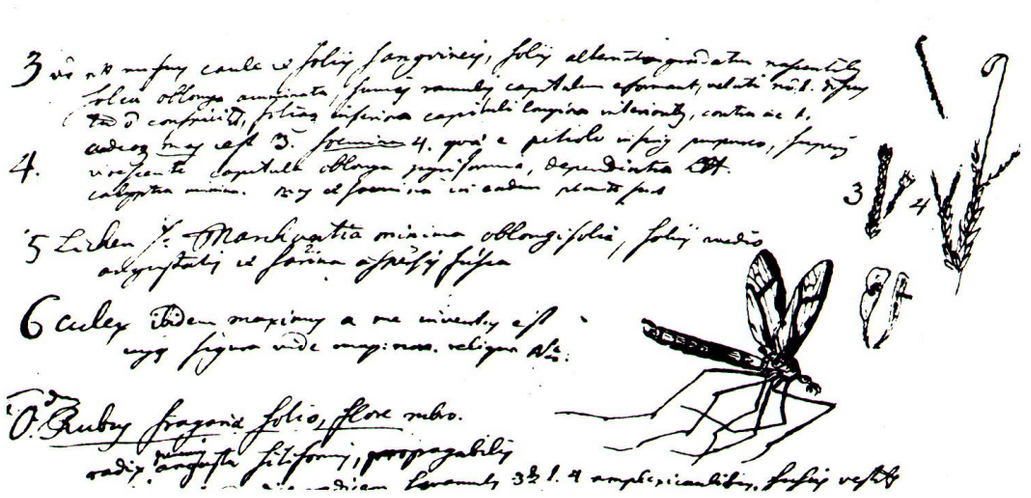

FIG. 20 A page from Linnaeus's journal, which he kept during his journey of 1732, bears this sketch of *Tipula rivosa* (now known as *Pedicia rivosa*), probably undertaken with the low-power lens which still survives with his microscope (Fig. 19). The venation of the insect wings shows with remarkable clarity.

as a token, in response to some indication from the recipient that it would be a suitable gift. It would be tempting to conclude that it was the instrument he took with him to Lapland in 1732 (just six years earlier) but it is not in any way a portable microscope, and there are no indications that he planned sufficient microscopical work to make it worth while transporting anything so bulky. Perhaps it was a microscope which he used in Paris, in the continuance of his studies. But it must be said that compound microscopes of this sort were more decorative than functional, more so where serious and detailed scientific work was in view.

Some simple microscopes were not capable of use as high magnification microscopes, but were made purely for dissection. Of these, one of the best known is the botanical microscope invented by William Withering (1741–1799) late in the eighteenth century. It took the form of a basic little microscope mounted into the lid of a box, with a chain to pull it into the upright position as the box itself was opened. The instructions read:

> When the [floral] parts in question are very minute, and require a nice and careful dissection, place the microscope upon a table, and raise it, if necessary, on a book or two, so that the eye may be applied with ease immediately over and close to the glass (b). Lay the object to be examined on the dark stage (c) until you see the object upon the stage perfectly distinct. With the needle in the left, and the knife in the right hand, the elbows resting on the table, proceed in the dissection at the same time that the eye is applied to the glass (b).
>
> When the microscope is shut up, the instruments and the hand-glass are to be put into the cells destined to receive them, and the whole forms a shape and size convenient to carry in the pocket.

The lenses were not of fine quality, and had a limited magnification. It is partly because of microscopes like Withering's, which doubtless had a use for low-power work in the field, that single-lensed microscopes came to be viewed as dissecting instruments. They were nothing of the sort – as we will see, they reached surprising (and, today, scarcely recognised)

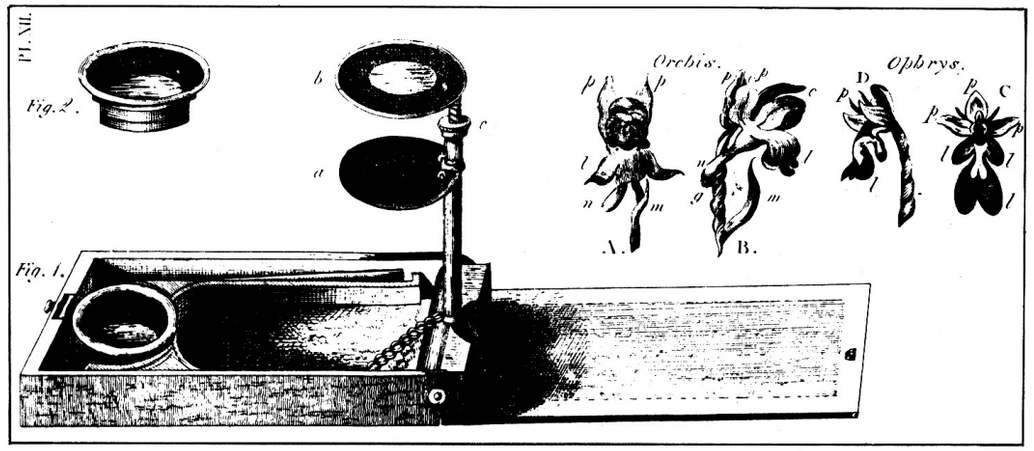

FIG. 21 William Withering's pocket microscope was a true dissecting instrument, and was not intended for high-power magnifications. It is not well designed; a hand-lens might have been better for field use.

optical performance. I am inclined to think that Withering was not entirely as convinced of the value of his microscope as his advertisements for it suggest, either: many of the illustrations in his book on the British flora – published under the title *Withering's Botanical Arrangement* – were surely carried out with a better instrument by far.

William Withering himself came from a herbalist's family: his father was an apothecary and young William was sent to Edinburgh School of Medicine. The then Professor of Medical Chemistry, William Cullen (1710–1790), was a prominent physician, a specialist in herbal medicine who had introduced many such remedies into practice with considerable success. Withering graduated in 1766 and seemed unlikely to make his mark in botany: in spite of his background, his upbringing and his training, he seemed ill-disposed towards botany. When he was told by John Hope, Professor of Medical Botany, that he might well win a gold medal if he did well in botany, he still wrote that even such an inducement did not make the subject seem attractive. He disliked botany intensely. Yet, within a decade of graduating, he had published the first edition of his *Botanical Arrangement* in 1776.

The reason for this flowering of interest was a woman. Withering fell in love with Helena Cookes, an artist whom he met through her father after moving to set up practice in